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LEXINGTON PROJECT REPORT

NO. 143

TOLERANCES AND SHIELDING REQUIREMENTS

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Jerry E. Keyes
Authorizing Official
Date 3-5-98

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ABSTRACT

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Lexington Project Report #143

Title: Tolerances and Shielding Requirements
Author: L. W. Nordheim
Date: September 2, 1948
Place: Lexington

Note: This report represents an earlier, and largely independent, set of estimates such as are given in Chapter IVB, REQUIREMENTS.

The following tables, are given which contain a synopsis of data which are important for the determination of shielding requirements. They are intended to permit rapid orientation in this field and to furnish a basis for comparison of different type crafts. Justification for and, in most cases, an extensive discussion of the quoted figures are given in other reports. (LP-126, LP-146, LP-151, and Chapter IVB of The Final Lexington Report.) It should be emphasized that there are serious uncertainties in many cases, and that considerable further experimental work would be required before some of the figures could be trusted.

A. Table 1 shows the fluxes of fast neutrons and hard gamma rays from a completely unshielded reactor of 10^5 kw. power output. There will be a partial self-shielding of the reactor which will depend on its structure, that is, size and composition. The most unfavorable case has been assumed, that is, a small fast reactor without reflector. Only fast neutrons and hard gamma rays are shown since they constitute the most dangerous groups which are at the same time the most difficult to shield against. The energy escaping the reactor is also given, since it produces some important effects through ionization of the air around the plane.

Table 1

Radiation Fluxes from an Unshielded 10^5 KW. Reactor at Various Distances

	Type of Radiation	
	Fast Neutrons	Hard Gamma Rays*
Flux (per sq. cm. sec.)		
Distance = 1 m.	3×10^{13}	10^{14}
10 m.	3×10^{11}	10^{12}
1000 m.	10^8	10^8
Energy Outflow (kw.)	0.5×10^3	1.5×10^3

It may be added that about 10^{-3} of the energy outflow, i.e., 2×10^{-5} of the pile energy, will appear as visible light.

* Includes provision for capture gamma rays which, strictly speaking, are largely absent in an unshielded reactor, but which will be present as soon as a moderate amount of shielding is provided.

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B. Table 2 lists the tolerance doses for various sensitive components. They are based on the maximum irradiation intensity they can receive without seriously impairing their operational efficiency over a period of twenty-four hours. Explanatory remarks are given below the table.

Table 2

Permissible Radiation Fluxes

	Component	Fast Neutrons/ sq. cm. sec.	Hard Gamma Rays/ sq. cm. sec.	Energy Outflow kw.
(1)	Man	2×10^4	3×10^5	
(2)	Aerial Photographic Films	3×10^4	5×10^2	
(3)	Payload	10^8	10^{11}	
(4)	Guidance		10^{10}	2
(5)	Radio and Radar Transmission			2
(6)	Electronic equipment	10^{11}	10^{11}	
(7)	Lubrication oils	10^{11}	10^{11}	

Remarks:

(1)--corresponds to 1 Roentgen per hour. Irradiation of 25 R total does not produce any clinically observable effects.

(2)--important for photo reconnaissance. Though it appears that the sensitivity to gamma-radiation of currently used film for aerial photography is very high, the provision of some extra shielding for it would not seem to create a serious difficulty.

(3)--based on the present-day atomic bomb. The latter is fairly sensitive to an external flux of fast neutrons. The uncertainty here is rather high.

(4)--based on star-tracking systems. Figures are very uncertain. Nuclear power certainly makes guidance more difficult. The limiting factors are response of the photosensitive surface to gamma-radiation, and stray light from the cloud of ionization around the plane.

(5)--the limiting factor lies in break-down of high voltage due to ionization; the figure is very uncertain.

(6)--some components generally used cannot stand the quoted intensities. However, it is believed that substitutes can be found, that will stand up under such conditions.

(7)--it is possible that lubricants can be found which will be able to stand somewhat higher radiation, or that tricks such as filtering can be used.

C. Using Tables 1 and 2 we can arrive at required attenuation factors for the three aircraft types which are under consideration. A power output of 10^5 kw. is assumed, and also that the most sensitive components are placed at a distance of 10 m. from the reactor. Only orders of magnitude are significant.

Table 3

Required Attenuation Factors

Aircraft	Fast Neutrons	Hard Gamma Rays
Manned	2×10^7 (man)	3×10^6 (man, film)
Tug tow	10^4 (man)	10^3 (man, film, intercommunication)
Pilotless	10^4 (payload)	10^2-10^3 (electronics, guidance)

The most sensitive components which determine the attenuation factors are also indicated. For the tug-tow, man is still the determining factor, with a possibility that transmission of radio signals from the tug to the tow may already be impaired by the ionization around the plane. For a pilotless plane, the neutron tolerance is set by the payload, the gamma-ray tolerance in all probability by the guidance equipment. If star tracking can be avoided, shielding may be further reduced; if not, the given figure may not be even sufficient.

It should be remarked that there is an additional problem in the handling on the ground of a partially shielded plane, particularly if the plane or at least the reactor material is to be recovered. In case of insufficient neutron shielding the airplane will acquire induced activities. The accumulated fission products will emit, half an hour after shut-down, a gamma radiation of order 1% of the intensity during operation, and this activity decays only slowly with time. Even in the case of the tug, considerable precautions will be required for approaching the plane; these will have to be the more elaborate the more the shielding is reduced.

A comparison of the three types considered shows that the attenuation factors in the manned plane are about the square of those in the tug case.

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The shield thickness in the latter case will thus be about one-half of the manned plane. It seems hardly possible, on the other hand, to reduce the shielding for a pilotless guided missile, carrying payload, substantially below that of the tug tow arrangement.

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